EFFECTS OF SPLIT APPLICATION OF FERTILIZER AND PLANTING DENSITY ON YIELD, COMPONENTS OF YIELD AND OTHER AGRONOMIC CHARACTERS OF RICE (II)

by

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In the previous experiment, it was indicated that split application of nitrogen and potash fertilizers considerably increased the grain yield of rice in comparison with that of conventional method of fertilization (Chang and Yang, 1964). This result, however, was obtained in the second crop and it is necessary that the effect of split application of fertilizer should also be evaluated in the first crop, since the growing condition between these two crops may be quite different.

Suzuki (1958) and Matsuwura (1963) have recommended certain splitting ratios and time for applying split portions of nitrogen fertilizer. However, the optimum times of splitting nitrogen fertilizer are still unknown. Although Sheng and Yuan (1964) obseved a favorable effect of split application of potash fertilizer, they were apparently unable to decide from their experiment how many times the potash fertilizer should be splitted for rice. The necessity of split application of phosphoric fertilizer also needs to be clarified, even though it is generally regarded as unnecessary (Mitsui, 1954).

The objectives of this study were (1) to compare the effects of several methods of split fertilization, (2) to evaluate the necessity of split application of phosphoric fertilizer, and (3) to clarify the relationship between split application of fertilizer and planting density in the first crop of rice.

MATERIALS AND METHODS

Two series of treatments namely, fertilizer application and planting density were arranged in a factorial experiment. The application of fertilizer (factor one) was tried at four levels. They were conventional method of fertilizer application as check and three sets of split fertilization. In the Conventional Method of Fertilization, all of P, K, and half of N were applied as a basal dressing and the balance of N applied as a top-dressing at the time of second weeding or 30 days after transplanting. The Split Fertilization 1 was carried out by applying 2/3 of P, K, and 1/5 of N as a basal dressing, 2/5 of N as first top-dressing applied at the time of second weeding or 30 days after transplanting, and the remaining 1/3 of P, K, and 2/5 of N used as second top-dressing at 60 days after transplanting. The Split Fertilization 2 was proceeded by applying 2/3 of P, K, and 4/10 of N as a basal dressing,

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3/10 of N as first top-dressing at the time of second weeding or 30 days after transplanting, and the remaining 1/3 of P, K, and 3/10 of N as second top-dressing at 60 days after transplanting. In the Split Fertilization 3, 2/3 of P, 3/5 of K, and 3/10 of N were applied as a basal dressing, 3/10 of N as first top-dressing at the time of second weeding or 30 days after transplanting, 1/3 of P, 2/5 of K, and 3/10 of N as second top-dressing at 60 days after transplanting, and the rest of 1/10 N applied as third top-dressing at 80 days after transplanting. The total amount of fertilizers used in this experiment was 80, 40, and 40, kg per hectare for N, P, and K, respectively in four methods of fertilization. For the planting density (factor two), there were two levels namely, 64 hills per *Pen* or 3.3 m^2 and 96 hills per *Pen.* Thus two factors, one at 4 levels and the other at 2, formed a 4×2 factorial. The experiment was arranged in randomized blocks with four replications.

The *Japonica* rice variety, Chianung 242 was used in this experiment. It was transplanted on January 30, 1964 and harvested on June 12, 1964. The plot was 4×2.5 m in size which was equal to 10 m^2 or 1/1000 hectare. Approximately 5 seedlings were transplanted in each hill. The distance between rows was 24 cm for both planting densities while the distance between hills within a row was 21.5 cm and 14.3 cm for 64 hills and 96 hills per 3.3 m^2, respectively.

Plant height and number of tillers per hill were recorded at growing and maturing stages. Heading date was recorded as the number of days from transplanting to about half of ear-bearing tillers being completely headed. The length of internodes, number of grains per panicle, weight of panicle, length of panicle and weight of 1,000 grains were measured for each plot based on 20 randomely sampled plants on the day before harvestings, and the grain yield was based on the total grain yield of each plot.

All data collected were subjected to the analysis of variance. For the data of lodging and blast disease occurrences, arcsin transformation was made before conducting analysis.

This experiment was conducted at Chiayi Agricultural Experiment Station in the first crop of 1964.

RESULTS AND DISCUSSION

Effects of the Application of Fertilizer and Planting Density on Yield and Components of Yield.

The average yield, components of yield, and F values from the analysis of variance are given in table 1.

It was indicated in table 1 that split fertilizations generally produced better yields than conventional one. The yield of Split Fertilization 1 was slightly less than that of the Conventional one, indicating that the former treatment was not superior to the latter one. It is interesting to note that the former method yielded more than the conventional one in the 2nd crop of the previous year (Chang and Yang, 1964) Since the experimental field and rice variety were the same in both experiments,

Table 1. Means and F values of grain yield and components of yield of rice variety Chianung 242 under different methods of fertilization and planting densities

Treatments	Grain Yield (kg/ha)	Number of panicles per hill	Number of grains per panicle	weight of 1,000 grains (g)
Fertilization				
Conventional	5,553	11.3	114	29.4
Splitting 1	5,503	13.9	124	27.7
Splitting 2	5,724	12.2	120	27.5
Splitting 3	6,150	12.2	130	28.7
F values	4.04*	7.33**	2.47	3.90*
LSD 5%	430	1.1	—	1.3
Planting density				
64 hills	5,501	13.5	124	28.1
96 hills	5,964	11.3	121	28.6
F values	10.04**	32.0**	0.59	0.90
LSD 1%	414	1.1	—	—
Fertilization x planting density F values	0.66	0.48	1.35	0.76

* Differences significant at the 5% level.
** Differences significant at the 1% level.

the difference in effectiveness of the Split Fertilization 1 may be due probably to the difference in the growing conditions of the two crops and also to the time of fertilization.

The Split Fertilization 2 produced 171 kg more grains than the conventional one, the difference, however, failed to reach the 5% level of significance. The times of splitting, the splitting ratios for P, K, and the time of applying fertilizers were the same for Split Fertilizations 1 and 2. The only difference between these two methods was the splitting ratio of nitrogen. The splitting ratios for basal, first top- and second top-dressings were 2:4:4 and 4:3:3, respectively for Split Fertilizations 1 and 2. Thus, the increase of yield by Split Fertilization 2 seemed to be associated with the splitting ratio of nitrogen. It was also apparent from the results that lower ratio of nitrogen for top-dressings gave a better chance of obtaining a higher yield than the higher one.

Grain yield per hectare of the Split Fertilization 3 was 579 kg or 10.75% higher than that of the Conventional one, a difference greatly exceeded the 5% level of significance. In the Split Fertilization 3, nitrogen fertilizer was splitted 4 times with the ratio of 3:3:3:1 which differed from the Split Fertilization 2 simply by removing one part from the basal-dressing and adding one more top-dressing at 80 days after transplanting. The splitting ratio of potash fertilizer was also different between the two methods. It was 6.7:3.3 in the Split Fertilization 2 while that of the Split Fertilization 3 was 6:4, a slightly hevier dose for the top-dressing in the

latter one. It is probable that these adjustments of splitting ratios of nitrogen and potash fertilizers contributed to the substantial increase of yield in the Split Fertilization 3. There was also an indication that, under the prevailing conditions of this experiment, the times of splitting nitrogen fertilizer seemed to be positively associated with the increase of grain yield. However, it is also apparent that times of splitting should be well coordinated with splitting ratios if the maximum yield is to be expected.

The times of splitting, splitting ratio and time of application of phosphoric fertilizer were the same for the Split Fertilization 1, 2, and 3. Apparently, the differences in yield of these three split fertilizations were not related to the split application of phosporic fertilizer. Furthermore, the Conventional Fertilization, where all phosphoric fertilizer was used as a basal dressing, yielded as much as the Split Fertilization 1, indicating that split application of phosphoric fertilizer may be unnecessary. The results obtained in this expriment confirmed the report of Mitsui (1954) who suggested that sufficient amount of phosphoric fertilizes applied as a basal dressing would be enough to cover the need for a maximum yield. However, for a particular type of paddy, split application of phosphoric fertilizer might be necssary.

The time of applying top-dressings also plays an important role to the effectiveness of split fertilization. For two top-dressings, Matsuwura (1962) suggested that the first top-dressing comes at maximum tillering stage and the second top-dressing comes at ear primordia formation stage. However, in case of three top-dressings, the time for applying each top-dressing is still not clearly defined. In this experiment, the second top-dressing was made at 60 days after transplanting for all three split fertilizations. The average heading date for the split fertilization was 99 days after transplanting. According to Yuan *et al.* (1960), Chianung 242 took 39 days to heading from the beginning of the floral differentiation in the first crop. Therefore, the time of second top-dressing was equivalent to the stage of floral primordia differentiation. The third top-dressing was made at 80 days after transplanting which was estimated to be between the stages of spiklet and pollen mother cells differentiations (Matsushima and Manaka, 1956). Matsuwura (1962) reported that top-dressing of nitrogen at the milk ripe stage is still effective. Further investigations are, therefore, necessary to determine the appropriate time of applying each top-dressing of nitrogen fertilizer.

The fertilizations significantly increased the number of panicles per hill, substantially increased the number of grains per panicle but significantly reduced the weight of 1,000 grains. It would appear that the increase in yield of split fertilizaton was due primarily to the increase of the number of panicles per hill. The increase in number of grain per panicle, even though statistically insignificant, might have also contributed greatly to the yield increase. A similar observation on the response of yield components was also made by Frey (1959) who noted that in oats, yield

increases by nitrogen fertilization were due to increases in the number of heads per plant and a greater number of seeds per head. It should be noted, however, that yield increase of split fertilization in the previous experiment (the second crop, 1963) was the major contribution of the increase in the weight of 1,000 grains (Chang and Yang, 1964). The significant reduction in the weight of 1,000 grains in this experiment appeared to be caused by the high percentage of lodging and heavy occurrence of neck blast in the plots of split fertilization.

High planting density of 96 hills per 3.3 m^2 produced 463 kg or 8.41% more grain yield per hectare than that of low planting density of 64 hills per 3.3 m^2, a difference greatly exceeded the 1% level of significance. Since the components of yield were adversely affected by high planting density except the weight of 1,000 grains which remained unchanged, it became apparent that the yield increase in high planting density was contributed entirely by the increase of panicles per unit area. The total number of panicles per plot was calculated as 2,430 in 64 hills per 3.3 m^2 while that of 96 hills per 3.3 m^2 was 3,051, an increase of 621 panicles or 25.50%. The tendency of the increase was similar to that of the previous experiment (Chang and Yang, 1964).

No significant interaction between fertlization and planting density was evident in grain yield and components of yield.

Effects of Fertilizer Application and Planting Density on some Agronomic Characters.

A summary of the data and F values computed for several agronomic characters are presented in table 2.

Heading date of split fertilizations was similar to that of conventional one except Split Fertilization 1 which headed two days later. The relatively high dosages of the first top- and the second top-dressings probably induced the delay of heading in plots of the Split Fertilization 1. Heading date was almost the same in both planting, indicating that planting density did not affect the date of heading.

The number of tillers and plant height were both significantly suppressed by split fertilizations at the early stage of growth, However, at the mature stage, the ear-bearing tillers and plant height were significantly higher in the plots of split fertilizations. The number of tillers and plant height in the plots of high planting density were consistently lower than low planting density throughout the growing period. The panicles were heavier and longer in the plots of split fertilizations than those of conventional one. The differences, however, were not significant. In the previous experiment, these differences reached the level of significance. Planting density apparently did not affect both the weight and length of panicles.

Split fertilizations slightly reduced the occurrence of leaf blast, but significantly increased the occurrence of neck blast, especially the Split Fertilization 1. The second top-dressing which provided more nitrogen available to rice plants, seemed to faver a severe occurrence of the neck blast in the plots of split fertilizations, the heavier the dosage, the more serious the disease. If the neck blast were more

Table 2. Means and F values of some agronomic characters of rice variety Chianung 242 subjected to the treatments of fertilization and planting density

Treatments	Heading date (days)	Number of tillers per hill	Plant height		Panicle		Leaf blast (%)	Neck blast (%)
			50 days (cm)	Full ripe (cm)	weight (g)	length (cm)		
Fertilization								
Conventional	98	17.0	53.5	110.0	3.16	21.7	25.0	1.0
Splitting 1	100	15.2	51.4	119.7	3.32	22.1	25.0	30.1
Splitting 2	98	16.1	51.0	117.7	3.26	22.2	22.1	8.4
Splitting 3	99	14.6	49.3	118.3	3.47	22.7	22.1	7.5
F values	2.96	3.96*	3.20*	23.71**	1.16	2.29	0.64	6.35**
LSD 5%	—	1.6	2.9	2.7	—	—	—	5.2
Planting density								
64 hills	99	16.9	51.7	116.8	3.30	22.1	25.0	13.1
96 hills	98	14.5	50.9	116.0	3.30	22.3	22.1	6.5
F values	1.86	20.59**	0.78	0.73	0	0.33	1.91	2.06
LSD 1%	—	1.5	—	—	—	—	—	—
Fertilization x planting density F values	1.65	2.64	1.22	0.86	1.82	1.09	0.64	0.94

* Differences significant at the 5% level.
** Differences significant at the 1% level.

effectively controlled, the increase of yields in the plots of split fertilizations might have been more remarkable. Therefore, it is suggested that in the first crop of rice more attention should be paid on the control of rice blast disease in the actual practice of split fertilizations. The occurrence of rice blast disease was not affected by planting density.

In all characters analyzed, the interactions between fertilization and planting density appeared to be not significant.

Effects of Fertilizer Application and Planting Density on the Length of Internodes and Lodging.

The average length of internodes, the percentage of lodging and F values obtained from the analysis of variance for these two characters are summarized in table 3.

Rice plants in the plots of split fertilizations were found to have longer internodes than those of the conventional one, the differences being significant except the first internodes. The differences in the third and the fifth internodes were particulary impressive, where the Split Fertilization 1 and 3 appeared to have the longest internodes. Since the percentages of lodging were also the highest in these two split fertilizations, it would appear that the third and fifth internodes of rice plants could be associated with lodging, and the longer the internodes, the easier the lodging. It should be noted, however, that the split fertilizations stimulated the growth of internodes and thus induced a severe lodging of rice plants in the first crop,

Table 3. Means and F values of the length of internodes and the percentage of lodging of rice variety Chianung 242 under different methods of fertilization and planting densities

Treatments	Length of internodes (cm)					Lodging (%)
	1st.	2nd.	3rd.	4th.	5th.	
Fertilization						
Conventional	40.8	20.3	13.5	8.7	2.0	19.1
Splitting 1	40.7	21.2	15.1	9.7	2.8	59.4
Splitting 2	40.7	21.2	13.5	8.3	2.0	29.4
Splitting 3	40.7	21.9	14.7	9.4	3.4	48.1
F values	1.60	3.41*	5.28**	4.81*	6.92**	5.50**
LSD 5%	—	1.0	1.1	0.9	0.8	5.60
Planting density						
64 hills	40.6	21.2	14.5	9.3	2.5	31.3
96 hills	41.4	21.1	13.9	8.7	2.6	45.6
F values	4.22	0.01	2.86	3.86	0.15	3.28
Fertilization x planting density F values	1.10	0.76	1.16	1.00	0.60	0.20

* Differences significant at the 5% level.
** Differences significant at the 1% level.

while in the previous experiment (Chang and Yang, 1964) it was observed that the split fertilization reduced the length of internodes and thus significantly prevented the occurrence of lodging. The excessive elongation of internodes at the lower parts of the culm and the severe lodging occurred in the plots of split fertilzation might be partly the result of early application of the second top-dressings or so-called "panicle fertilization", since it was applied about 39 days before heading in this experiment. Further investigations should be made to work out a formula for the complete solution of all hazards threatening split fertilization in the first crop of rice.

The length of internodes and lodging were not significantly affected by planting density. However, there was an indication for high planting density to have higher percentage of lodging. A similar tendency was also revealed in the previous experiment (Chang and Yang, 1964).

The interactions between method of fertilization and planting density were not significant in both length of internodes and percentage of lodging.

SUMMARY

The rice variety, Chianung 242 was subjected to 4 levels of fertilization and two levels of planting density arranged in a 4×2 factorial oxperiment with four replications. The experiment was conducted at Chiayi Agricultural Experiment Station in the first crop of 1964. Data on grain yield, components of yield and

several other agronomic characters were taken to analyze the effects of the treatments as well as their interactions.

Split fertilizaions generally produced higher yields than conventional one, a difference exceeded the 5% level of probability. The yield increase appeared to be due largely to the increase of panicles and grains.

Responses of grain yield as well as other agronomic characters measured to the split application of phosphoric fertilizer were not evident. However, there were indications for the effects of split applications of nitrogen and potash fertilizers.

Splitting nitrogen four times with the ratio of 3:3:3:1 during the entire period of growth gave, so far, the highest grain yield. Higher dosages of nitrogen applied at the first top- and second top-dressings resulted in the decrease of grain yield, severe occurrence of neck blast disease and lodging, suggesting that splitting ratio of 6:3:3 was better than that of 2:4:4 under the conditions of this experiment. For potash fertilizer, the splitting ratio of 6:4 gave better grain yield than that of 6.7:3.3. Applying first top-, second top-, and third top-dressings at stages of maximum tillering, floral primordia differentiation and spiklet and pollen mother cell differentiations, respectively, appeared to be effective. However, other alternatives should also be explored.

The high planting density produced higher yield than lower one, a difference exceeded 1% level of probability. The yield increase was attributable to the increase of panicles per unit area.

Rice plants in the plots of split fertilizations generally tillered less with shorter culms in the early stage of growth, but they overgrew those of conventional fertilization for these characters at the maturing stage. The panicles of split fertilizations were generally heavier and longer than those of coventional one. Number of tillers, plant height, panicle weight and panicle length were generally decreased in the plots of high planting density.

Split fertilzations significantly stimulated the occurrence of neck blast disease which, in turn, caused a reduction in grain weight. Planting density did not affect the occurrence of rice blast disease.

Split fertilizations significantly increased the length of internodes especially that of the third and the fifth internodes. The elongation of internodes, especially at the third and the fifth, seemed to be related to the severe lodging of the plots treated with split fertilizations. The results suggested that the practice of split fertilization in the first crop should take into account the occurrence of blast disease and lodging. Planting density did not cause a significant change in the length of internodes. However, there was tendency for a high planting density to accompany a higher percentage of lodging.

There were no significant interactions between the split application of fertilizers and planting density for all the characters measured in this experiment.

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水稻肥料分施與栽植密度對產量，產量構成因子及其他主要農藝性狀之效果（二）

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摘　要

本試驗仍分肥料施用法與栽植密度兩因子。肥料施用法（第一因子）分4個變級，即慣行施肥法（基肥，N 1/2, P, K 全量，全層施肥；第一次追肥，N 1/2 於插秧後30日施用），分施法1（基肥，N 1/5, P, K 2/3，全層施肥；第一次追肥，N 5/2 於插秧後30日施用；第二次追肥 N 2/5, P, K 1/3 於插秧後60日施用），分施法2（基肥 N 4/10, P, K 2/3，全層施肥；第一次追肥 N 3/10，於插秧後30日施用；第二次追肥 N 3/10, P, K 1/3 於插秧後60日施用），與分施法3（基肥 N 3/10, P 2/3, K 3/5，全層施肥；第一次追肥 N 3/10 於插秧後30日施用；第二次追肥 N 3/10, P 1/3, K 2/5 於插秧後60日施用；第三次追肥，N 1/10 於插秧後80日施用）。栽植密度（第二因子）分兩個變級，即慣行栽植密度（每坪64株）與密植（每坪96株）。兩個因子計得8種試項，隨機區集設計重覆4次。本試驗於民國53年第一期作，在嘉義農業試驗分所舉行，以明瞭各因子對第一期作水稻產量及主要農藝性狀之效果。茲將所得結果摘要如下：

肥料分施，除分施法1外，均較慣行施肥增產，其增產原因爲每株穗數與每穗粒數增加所致。分施法3產量最高，每公頃乾淨谷較慣行法增加579公斤，達10.75%，差異顯著。氮肥分施以4次最佳，惟每次追肥量所佔比例似不宜過高。鉀肥分施兩次有效但磷肥分施效果不明。密植對慣行栽植密度每公頃乾淨谷可增加463公斤，達8.41%差異極顯著。其產量之提高乃得自單位面積內總穗數之增加。

水稻初期發育顯受肥料分施抑制，分蘖與株高，肥料分施區者均顯著低減。惟在發育後期，穗數，株高，穗長與穗重均以肥料分施區者爲優。肥料分施顯著減低谷粒千粒重。生育日數與叶稻熱病之發生受肥料分施影響較少，但穗頸稻熱病之發生，則因肥料分施而顯著增加。分蘖與穗數隨栽植密度之增加而顯著低減，其餘農藝性狀亦有類似趨勢，惟差異均不顯著。

稻莖第一節間以下各節間長度均因肥料分施而顯見增加，尤以第三節間及第五節間爲最。第三節間與第五節間長度與倒伏似有密切關係，因該節間愈長，其倒伏百分比亦愈高。密植亦有增加倒伏之趨勢，惟差異未達顯著水準。

肥料分施與栽植密度之間似無顯著之交感作用存在。